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remarkably interesting paper on modern glacial striæ, of which unfortunately no report is available: Mr. W. W. Watts contributed a note on the basins of some of the tarns near Snowden. One very small one seemed to occur in a rock basin, one was dammed at both ends by scree and stream detritus, and two larger lakes, Glaslyn and Llyn Llydaw, were either confined in true rock basins or else were not more than about 40 feet deep.

A large number of excursions was planned and carried out chiefly under the leadership of the President and Mr. Clement Reid. The various localities for the Coralline and Red Crag deposits were visited and the relations of the deposits studied, and the last two days were devoted to a pretty thorough examination of the remarkable and classical glacial deposits of Cromer on the coast of Norfolk.

W. W. Watts.

Geological Survey, London.

A COURSE IN ASTRONOMY FOR ENGINEERING STUDENTS.

At the present time our engineering schools tend more and more strongly to technical curricula which deal with professional subjects to the exclusion of nonprofessional matters, and the author of the present paper, approving this tendency, purposes to state here his conception of a brief course in spherical and practical astronomy as a part of the technical training of the future engineer. The purposes of such a course should be:

(A.) To give the pupil some training in the precise use of instruments of precision. His course in surveying has given the student an introduction to the use of such instruments, but the nature of that work and the circumstances under which it is done preclude the placing of any considerable emphasis upon precision of results. To demand all the accuracy which a transit or level can be made to furnish is in general bad surveying practice, but only the man familiar with refined methods of instrumental work is competent to form an intelligent judgment of the manner in which those methods should be modified and their rigor relaxed in any given case. The course in astronomy, therefore, comes as a supplement to that in surveying, and the pupil should now be taught:

(a.) That it is his business in each of his problems to obtain from his instrument all of the precision that it can be made to furnish.

(b.) He should be taught to obtain this precision with a minimum expenditure of care and time. The instinctive tendency of the student mind to execute every part of a given task with equal painstaking needs to be curbed and the pupil taught what things require minute care and what may be, and ought to be, dealt with in a summary manner.

(c.) As a subordinate matter he may be introduced to the use of instruments of a higher grade than those employed in his course in surveying.

(B.) A second purpose of the course is to train the student in the art of computing (ciphering). Model forms of record and reduction for his several problems should be placed before him and the advantage of compact and orderly arrangement of all numerical work should be strenuously insisted upon.

(C.) As the concrete outcome of the above training, the student should acquire the ability to determine latitude, time and azimuth with such instruments as he will use in the ordinary practice of civil engineering. The sextant and engineer's transit furnish quite as good an equipment for the course here contemplated as the elaborate outfit of an observatory. The latter belongs to a more advanced stage of study.

The details of a course of study such as is above suggested depend upon the amount

of time which can be assigned it in the curriculum, and as a compromise between conflicting interests we suggest a required course of sixty exercises, to be followed by an elective course, *which the student should have an opportunity to elect*, and for which he should receive credit.

THE REQUIRED COURSE. It is presupposed that the student is familiar, as a matter of common information, with the diurnal and annual motions of the earth and the rising and setting of stars. His technical instruction may begin with a formal definition of the zenith, poles, horizon, equator, meridian and an explanation of the coördinates, altitude, azimuth, declination, hour angle and right ascension, together with the geographical latitude and sidereal time, which should be introduced as concepts strictly analogous to the coördinates. An armillary sphere or some equivalent apparatus is almost essential to the ready acquisition of a working knowledge of the coördinates, and it will usually aid the student if emphasis is placed upon the fact that while any two coördinates suffice to fix the position of a star they naturally fall into pairs, altitude and azimuth, declination and right ascension, etc., the common element between the coördinates constituting a pair being that they refer to the same fundamental plane. It should be further noted that the latitude and sidereal time constitute the relationship between the different systems of coördinates, and it will be advantageous to point out the reasons for employing several different systems.

The astronomical triangle, Pole-Zenith-Star, should next be introduced as a device for transforming coördinates from one system to another, and the student's interest will be stimulated if it is pointed out to him that the practical problems with which he is soon to deal, such as the determination of time, latitude and the direction of the meridian, are in so far as their theory is concerned nothing other than cases of the transformation of coördinates.

The convenient use of the astronomical triangle for the purposes here indicated requires a knowledge of the 'general spherical triangle,' and it will frequently be found that the student's mathematical attainments are in this respect insufficient. In such cases it is often an economy of time to devote an hour to the derivation of the general formulæ of spherical trigonometry by the transformation of rectangular coördinates, accompanying the demonstration with the requisite precepts for the application of these formulæ to numerical calculation. The student should apply the astronomical triangle to the derivation of formulæ for passing from each system of coördinates to each of the others, and should preserve these formulæ for use in the reduction of his observations rather than to resort anew in each case to the triangle.

At this stage of progress the student should devote some little time to the numerical transformation of coördinates, both for the purpose of familiarizing himself with the several systems and mode of passing from one to another, and for instruction in the technique of computing, the arrangement of his work, the checks against the commission of error, the mechanical devices for economy of time and labor, and the use of addition and subtraction logarithms, which are usually neglected in the department of mathematics.

It is a common saying among experienced computers that the only way to avoid mistakes in numerical work is to have acquired experience through the commission of every possible kind of blunder, and there is perhaps no part of his course in astronomy from which the future engineer will derive more practical advantage than this training under the guidance and criticism of an accomplished computer such as every professor of practical astronomy should be.

This training in numerical work should be a prominent feature of the whole course in astronomy, and without more than a beginning in such work the student may pass to a consideration of the different kinds of time in the order, sidereal, apparent solar, mean solar time, and should learn the use of the ephemeris in so far as it deals with the concepts he has had occasion to employ. He will learn that the various quantities contained in the ephemeris are all variable with the time; that their values which he is to use must be interpolated from it for the instant at which the observation in question was made, and that this instant must be expressed in Washington or Greenwich time. This seems an exceedingly elementary matter, but it is the writer's experience that students are frequently perplexed by it and that a little care is required for its elucidation.

The order in which the student shall take up his practical problems is not a matter of primary importance, but it has been found convenient in practice to assign first the determination of time from a single altitude, or series of altitudes, of the sun, measured with the sextant, showing the student how to use the instrument and explaining its chief sources of error without going into their mathematical theory. The reduction of these observations brings the student to a consideration of the fact that the altitude which he has measured cannot immediately be employed with the latitude and declination of the sun for the solution of the astronomical triangle, but must be first transformed from an apparent into a true altitude by correcting for the effect of refraction and parallax.

The theory of the parallax may be briefly given, neglecting the earth's compression, but it will usually be better to give arbitrarily the refraction formula than to attempt its derivation. The student will usually have difficulty in determining which limb of the sun he observed, and his perplexity may be used to emphasize the advantage of observing both the upper and lower limbs. So also he will usually require some stimulus to secure the bestowal of sufficient attention upon the determination of the index correction.

The next step in his progress may be a rapid revision of the theory of the theodolite or engineer's transit which he encountered, but usually did not master, in connection with his course in surveying. This work should include the measurement of angles by repetition, the effect of a reversal of the instrument in eliminating its errors, the method of employing its plate and striding levels, and the mode of eliminating the effect of graduation errors. If an instrument with micrometer microscopes is available, instruction in its use may be given at this point and the instrument first employed for measuring the zenith distance of a terrestrial mark. It is advantageous to throw the alidade level somewhat out of adjustment, in order to impress upon the student that the reversal of the instrument eliminates all defects of this kind from the measured zenith distance.

Although not strictly germane to a course in astronomy, the subject of trigonometric levelling with the effect of refraction and the curvature of the earth's surface may be introduced here with advantage.

In his measurements of zenith distance the student should be taught to bring the level bubble somewhere near the middle of its scale, but not be allowed to spend much time in getting a nice adjustment of it, reading the level and subsequently applying its indications as a correction to the circle readings. This requires a knowledge of the value of a level division, and the student should be required to determine this value by whatever method his instructor deems most convenient.

Passing on to astronomical uses of the

theodolite, the student may determine latitude from circum-meridian altitudes of the sun (Gauss' mode of reduction) and azimuth from simultaneous readings of the vertical and horizontal circles when the line of sight is directed to the sun, combined with readings of the horizontal circle when the telescope is directed upon a terrestrial mark. This mode of determining azimuth, although very much neglected in the text-books, admits of considerable precision and is excellently adapted to the purposes of the engineer.

Thus far the student's problems have involved only work by daylight, but he should now take up night work and will require some instruction about illuminating the wires of his instrument and in reading verniers, levels, etc., by lamplight. His first problem should be the simultaneous determination of time and latitude from equal altitudes of Polaris and southern stars. This method is very little used in America, but it is the best method of using an engineer's transit for the determination of either time or latitude and should be taught to engineers. An exposition of the method with examples of its application has been given by the author of this paper in the Bulletin of the University of Wisconsin, Science Series, Vol. I., No. 3.

An average student with a good transit and ordinary watch may be expected within an hour to determine his latitude within 2″ and the error of his watch within a quarter of a second.

The limits of time above allotted permit the assignment of only one more problem in our course, the determination of azimuth from observations of a close circum-polar star. The student should be taught that while it is advantageous to observe at elongation it is by no means necessary to do so, and that by a proper combination of stars, together with an approximate determination of time, he may frequently avoid the necessity of observing at inconvenient hours without in any way impairing the precision of his results.

In outlining the above required course, to be given in sixty exercises, or less, no reference has been made to a text-book, and the author knows of no text-book which is altogether satisfactory. In giving at the University of Wisconsin the equivalent of the course above outlined it has been his practice to prepare cyclo-style copies of lecture notes covering the ground to be traversed by the class and including in detail the record and reduction of a set of observations corresponding to each problem assigned the student. A copy of these notes is placed in the hands of each student and he is expected to familiarize himself with the text contained in them and to use the numerical parts as models for the record and reduction of his own observations. These observations and their reduction written up in a note-book and accompanied by the requisite formulæ are preserved by the student as guides for any future work of the kind which he may have occasion to do. This mode of instruction, however, cannot be regarded as altogether satisfactory, and a suitable text-book would presumably strengthen the course.

It does not fall within the scope of this paper to provide in detail an advanced elective course in astronomy. As our schools are organized such a course must be arranged to meet the requirements of each individual case, but the material available for such a course in a properly equipped engineering observatory may be indicated as follows:

The Transit Instrument. Determination of time in the meridian. Investigation of the constants of the instrument. Determination of azimuth by mounting the instrument in the vertical of a circum-polar star near elongation.

Clocks and Chronometers. Comparison

of. Investigation of rates and temperature coefficients.

The Zenith Telescope. Investigation of constants. Determination of latitude.

The Universal Instrument. Refined determination of azimuth. Latitude from altitudes of stars. Time from transits over the vertical circle of Polaris, Doellen's method.

Transit Instrument in the Prime Vertical. Determination of latitude and declinations of stars.

The prosecution of such a course of study necessarily implies a considerable addition to the student's theoretical knowledge, and concurrently with his instrumental work he should take up in the standard treatises such subjects as precession, nutation, aberration, refraction, the reduction of star places, etc.; but we here approach, if indeed we have not already passed, the bounds which separate engineering study from the domain of the professional astronomer.

The points at which the writer of this paper seeks to place special stress are that a brief course in spherical and practical astronomy is properly a part of the professional training of every engineer in whose work surveying is to occupy an important place, and that this instruction can be advantageously given with no further instrumental equipment than that possessed by every good school of engineering.

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HOW FAR SHALL THE PERIODIC LAW BE FOLLOWED IN TEACHING CHEMISTRY?

MORE than a quarter of a century has passed since Mendeleeff announced the Periodic Law. Any one who critically surveys this period will be forced to admit that this discovery has been the most fruitful of results of any since the Atomic Theory, and I believe we are just beginning to realize the value of this Natural Law and to have some idea of the fulness of its true meaning.

Chemists have shown themselves very conservative in the adoption of such discoveries and the ordering of their science by means of them, but it seems that in this case they have carried their conservatism too far. And perhaps this conservatism has not always been that which springs from a careful guarding against the possibly false and misleading, but rather from mental inertia and a dislike of giving up the old and learning the new.

The Natural Law, if true, introduces some most radical changes into the science. It is in a measure subversive of the old. It is impossible to cling to the old system while ascribing high praise to the Periodic Law, as is done in so many of our text-books.

If this law is true it must dominate all of chemistry. Its statements are fundamental and all-embracing. It cannot consent to share its authority with the old system. There can be no half-way measures. Just in so far as it is accepted as proved it must be incorporated into the science. The custom has been to teach chemistry to beginners very much in the old style, and then to give a short time to explaining the Periodic Law, instead of teaching the science with this as the very foundation.

It is manifestly the duty of a conscientious teacher to satisfy himself as to how far this law is true, and then to make all possible use of it in his teaching, as he does of the Atomic Theory itself. If it is false reject it, if true let it be the foundation of your system of instruction.

Now let me say, at the beginning, that for myself, I regard this law as incomplete in several of its details. But some points of prime importance may be regarded as settled.

1. That the elements are not distinct and separate individuals, but are more or less